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## (54) Multipass evaporator.

(57) The performance of an evaporator made up of a plurality of heat exchange modules or units each having elongated, parallel upper and lower headers (14, 30) and a plurality of tubes (40) mounted between the headers (14, 30) with fins (44) extending between adjacent tubes (40) may be improved through the use of upper and lower manifolds (20, 36) wherein the upper manifold (20) is in communication with the upper headers (14) at one end (19) thereof and the lower manifold (36) is in fluid communication with the lower headers (30) at an end (34) thereof corresponding to the one end (19).

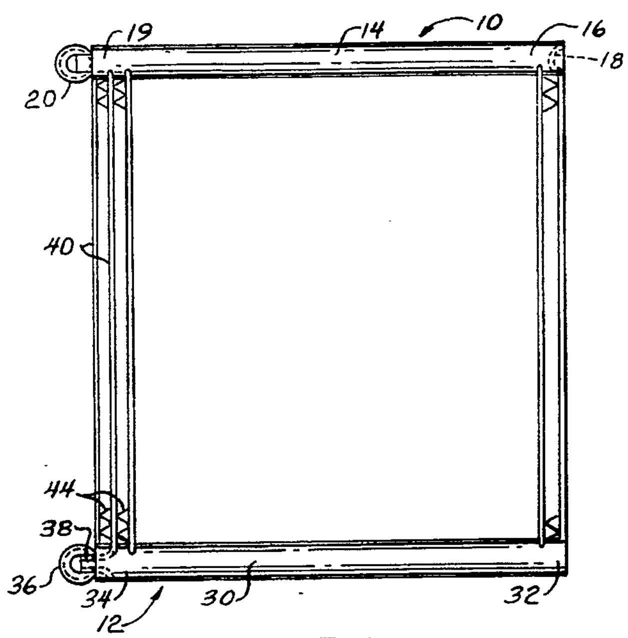


FIG. 1

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# MULTIPASS EVAPORATOR

## Field of the Invention

This invention relates to heat exchangers, and more particularly, to heat exchangers employed as evaporators.

## Background of the Invention

As is well-known, commonly employed air conditioning systems operating on a vapor compression cycle utilize evaporators as a means of cooling the air to be conditioned. A refrigerant is flowed through an evaporator and expanded therein. In so doing, the refrigerant absorbs its heat of vaporization, thereby cooling the medium with which it is in contact, typically heat exchanger tubes. The air to be conditioned is flowed over those tubes which are typically provided with fins for improved air side heat transfer. The air, at least locally, will be cooled below its dew point with the result that water will condense out of the air on the fins and on the tubes. This condensate must be removed or else it will freeze and plug the air flow path.

A variety of proposals for condensate removal have evolved and in their simplest form, involve the use of gravitational forces with a possible assist from the velocity of the air stream moving through the evaporator. These systems work rather well but frequently are unnecessarily bulky.

Furthermore, where relatively high velocity air streams may be present, as, for example, in vehicular air conditioning systems where fans operate at high speed to achieve maximum cooling in a short period of time, it is desirable to remove the moisture from the evaporator as quickly as possible to prevent it from being entrained in the air stream and entering the passenger compartment of the vehicle.

One evaporator structure that is ideally suited for use in situations that attend to the above concerns is disclosed in the commonly assigned United States Letters Patent 4,829,780 issued May 16, 1989 to Gregory G. Hughes, et al., the details of which are herein incorporated by reference.

As will be apparent to those skilled in the art, the Hughes, et al. evaporator provides excellent, low cost, light weight collection of condensate in the evaporator. Notwithstanding the foregoing, however, it remains desirable to fine tune such a structure so as to improve the usefulness of the same. The present invention is directed to accomplishing that goal.

## Summary of the Invention

It is the principal object of the invention to provide a new and improved heat exchanger. More specifically, it is an object of the invention to provide a new and improved heat exchanger which is ideally suited for use as an evaporator. It is also a principal object of the invention to provide an evaporator of the type disclosed in the previously identified Hughes, et al. patent and which has improved efficiency of operation.

According to one facet of the invention, there is provided an evaporator which includes a plurality of heat exchange modules or units each comprised of elongated, parallel upper and lower headers and a plurality of tubes mounted between the headers along their lengths and extending therefrom in side by side relation. The tubes, in the direction transversely of the headers, have a lesser dimension than the headers and the modules are stacked and assembled together with the corresponding tubes in the modules in alignment with each other. Fins extend between adjacent tubes in each module and upper and lower manifolds are provided. The upper manifold is in fluid communication with the upper headers at one end thereof and the lower manifold is in fluid communication with the lower headers at an end thereof that corresponds to the one end. This construction results in the manifolds being on the same side of the evaporator core and improves the performance of the heat exchanger as an evaporator.

According to another facet of the invention, such an evaporator is made up of at least two, and preferably three heat exchange units of the type mentioned above. Upper and lower manifolds are respectively in fluid communication with the upper and lower headers and at least one baffle is disposed in at least one and preferably both of the manifolds and located to cause fluid flowing through the evaporator to flow serially through the units in at least two, and preferably three, passes.

Use of an evaporator constructed according to this facet of the invention results in a more uniform outlet airside temperature which is indicative of a more uniform core surface temperature with no loss of performance over a single pass system. As a consequence of the greater temperature uniformity, the location of thermostatic temperature sensing tubes or the like within the core is less critical and the tendency for condensate in the vicinity of the lower headers to freeze is avoided.

According to still another facet of the invention, the heat exchange units are assembled generally as stated above to define any core. Baffles are located in at least some of the headers to cause fluid flowing in the evaporator to flow serially through parts of each module or heat exchange unit in at least two passes.

According to still another embodiment of the invention, a relatively narrow core having a depth of no more than about 2 inches or less is employed. According to this facet of the invention, serpentine fins having a fin density of at least eighteen fins per inch are employed.

Other objects and advantages will become apparent from the following specification taken in connection with the accompanying drawings.

Description of the Drawings

Fig. 1 is a front elevation of an evaporator made according to the invention;

Fig. 2 is a plan view of the evaporator;

Fig. 3 is an enlarged, fragmentary perspective view of a lower portion of the evaporator;

Fig. 4 is a fragmentary view of evaporator tubes and inter related fins;

Fig. 5 is a somewhat schematic view of a one pass evaporator illustrating temperature profiles;

Fig. 6 is a view similar to Fig. 5, but of a multipass, specifically a three pass, evaporator;

Fig. 7 is a view similar to Fig. 1, but of a modified embodiment of the invention;

Fig. 8 is a plan view of the embodiment of Fig. 7; and,

Fig. 9 is a side elevation of the embodiment of Figs. 7 and 8.

Description of the Preferred Embodiments

An exemplary embodiment of an evaporator made according to the invention is illustrated in the drawings and will be described herein specifically as an evaporator. However, in some instances, where its compactness as a heat exchanger is desirable, it may be utilized as other than an evaporator. The invention is intended to encompass such other uses.

As seen in Fig. 1, the evaporator includes an upper header, generally designated 10, and a lower header, generally designated 12. As seen in Fig. 2, the upper header 10 is comprised of a plurality of at least three elongated tubes 14 which are in side by side relation. The tubes 14, at their right hand ends 16, are sealed by plugs 18 (Fig. 1). At the opposite ends 19, the tubes 14 are in fluid communication with the interior of an upper manifold 20. Within the manifold 20 is a plug or baffle 22 and located so that one of the header tubes 14 is in fluid communication with one end 24 of the manifold 20 while two of the header tubes 14 are in fluid communication with the opposite end 26. In the embodiment illustrated, the end 24 of the manifold 20 may be an outlet for the evaporator.

The lower header 12 is made up of an identical number of elongated header tubes 30. The tubes 30 are in side by side, abutting relation as best seen in Fig. 3 and are brazed together as at 31 so as to be sealed to each other.

The right hand ends 32 of the tubes 30 are plugged by plugs not shown but similar to that shown at 18. The left hand ends 34 of the tubes 30 are in fluid communication with a lower manifold 36. Thus it will be seen that the upper and lower manifolds 20 and 36 are on the same side of the evaporator. Fittings 38 similar to conventional reducers may be utilized to establish fluid communication between the tubes 14 and 30 and the respective manifolds 20 and 36.

As more fully pointed out in the previously identified Hughes, et al. patent, the tubes 30, and optionally the tubes 14 as well, have a non-rectangular cross section which preferably is circular. A circular configuration for the tubes 14 and 30 defining the headers 10 and 12 as well as the manifolds 20 and 36 maximizes the burst pressure that the evaporator can withstand while utilizing a minimum of material for the fabrication of these components.

As seen in Fig. 1, the headers 10 and 12 are spaced but parallel and there are provided a plurality of parallel rows of parallel, flattened tubes 40. The number of rows of tubes 40 is equal to the number of tubes 14 or the number of tubes 30, in the illustrated example, three. The flattened tubes are in fluid communication with the interior of corresponding ones of the header tubes 14 and 30 and thus establish fluid communication between the headers 10 and 12. Thus, in the embodiment illustrated, incoming refrigerant or the like may enter the lower manifold 36 as illustrated by the broken arrow in Fig. 2. According to the invention, a baffle or plug similar to the baffle or plug 22 is also provided in the lower manifold 36 as schematically illustrated at 22' in Fig. 6. This location corresponds to that illustrated by the arrow 39 shown in Fig. 2, and will result in the refrigerant flowing upwardly through the tubes 40 associated with a first of the header tubes 14, downwardly through the tubes 40 associated with a second of the header tubes 14 and upwardly through the tubes 40 associated with the last of the header tubes 14 to exit the structure through the end 24 of the manifold 20. Thus, the embodiment illustrated is a three pass evaporator. Intended air flow through the evaporator is in the direction of an arrow 41 as shown in Fig. 2. As a result, refrigerant will be flowing from back to front through the evaporator core while air will be flowing from front to back through the core in what may be somewhat loosely termed a "countercurrent" type of flow.

The dimension of the tubes 40 transverse of the length of the tubes 14 and 30 is slightly less than the dimension of the tubes 14 and 30 to allow fabrication. The tubes 40 are inserted in elongated slots (not shown) in the tubes 14 and 30.

In the embodiment illustrated, as mentioned previously, there are three substantially identical rows of the tubes 40 and spaces 42 exist between each of the rows 40. This is a relatively small spacing and frequently will be on the order of 1/4 of an inch or less.

As seen in Fig. 3, corresponding tubes 40 and each of the rows of tubes 40 are aligned with each other, that is, on a common straight line. Thus, it will be appreciated that as described thus far, the evaporator is built up of a plurality of substantially identical modules or units, each made up of an upper header tube 14, a lower header tube 30 and a plurality of the flattened tubes 40. The modules are interconnected by the manifolds 20 and 36 as well as by the brazes 31. Serpentine fins 44 extend between adjacent flattened tubes 40 in each of the modules. As illustrated in Fig. 3, the serpentine fins 44 are common to each individual module but as pointed out in the previously identified Hughes, et al. patent, the fins 44 may extend between modules if desired.

As is well known, the crests of the serpentine fins preferably are brazed or otherwise bonded to the flat surfaces 46 of the tubes 40. If desired, the serpentine fins 44 may be provided with louvres shown schematically at 48. Fig. 4 illustrates fin density with the legend "FPI" which designates fins per inch. In Fig. 4, a fin density of eleven fins per inch is shown.

It has been found unexpectedly that where the depth of the core (measured as shown in Fig. 3) is relatively narrow, that is, no more than about two inches, performance of the evaporator improves as the fin density is increased from a conventional fin density or fourteen fins per inch to a fin density in the range of at least eighteen to twenty-four fins per inch.

Typically, such high fin densities are avoided in evaporators as it is expected they will reduce performance because the smaller spaces between fins are more prone to clog with condensate and thus prevent or hinder air flow.

Turning now to Fig. 5, the same illustrates a generally similar evaporator having an upper manifold 60 corresponding to the manifold 20, and a lower manifold 62 corresponding approximately to the manifold 36. Three rows of the tubes 40 are illustrated, but the headers 10 and 12 associated therewith are hidden by the manifolds 60 and 62.

In the evaporator illustrated in Fig. 5, none of the baffles 22 or 22' are utilized, with the consequence that a single pass evaporator is formed.

Air passing into the evaporator in the direction of an arrow 64 at a temperature of 77° F. exits the evaporator at a temperature that varies over a substantial range depending upon the top to bottom location of the air in relation to the evaporator core. Air exiting near the top of the core is at approximately 50° F. while air in adjacency to the lower end of the evaporator is exiting at approximately 32° F.

The latter condition is undesirable for condensate will tend to drain down the tubes 40 in the spaces 42 to collect at the junction of the lower header tubes 30 as more fully described in the previously identified Hughes, et al. patent. With temperatures on the order of the freezing point of water being present at the location of condensate collection, it will be readily appreciated that the possibility of freezing of the condensate and subsequent freeze up of the core is very real.

In contrast, when the baffles 22 and 22' are located as illustrated in an evaporator made according to the invention as illustrated in Fig. 6 to provide three or more passes, the air similarly moving in the direction of an arrow 66 and at the same temperature will exit the top of the evaporator at approximately 42° F. and exit the bottom of the evaporator at approximately 40° F. Thus, air temperature is much more uniform in an embodiment made according to the invention and for all intents and purposes, the evaporator of the invention has identical heat transfer performance to an evaporator such as that illustrated in Fig. 5.

This greater uniformity of air temperature minimizes the possibility of freezing of the condensate to prevent freeze up of the core. In addition, and as is well-known to those skilled in the art, thermostatic temperature sensing devices or tubes are frequently associated with evaporator cores for any of a variety of reasons. Because of the uniformity of air temperature, placement of such a temperature sensor on the core is not as critical as in prior art devices where such air temperature uniformity cannot be had.

In addition, utilizing the lower manifolds 30 as the refrigerant inlet and the upper manifolds 20 as the refrigerant outlet as illustrated in Fig. 6 and as previously described, and having both located on the same side of the core as shown in Fig. 1 also provides an increase in performance over other possible locations of the manifold and/or inlets and outlets.

Still another embodiment of the invention is illustrated in Figs. 7 through 9, inclusive. In this embodiment, there are a plurality of modules as before, each made up of an upper header tube 100, a lower header tube 102 and the plurality of flattened tubes 104 extending in generally parallel relation between the header tubes 100 and 102. The flattened tubes have a dimension less than the transverse dimension of the tubes 100 and 102 and serpentine fins 106 are interposed between the tubes according to the teachings of the previously identified Hughes, et al. Patent.

In this particular embodiment, tubular manifolds 108 and 110 are utilized and are associated with opposite ends of the header tubes 102. The manifold 108 acts as an inlet manifold, while the manifolds 110 acts as an outlet manifold as illustrated by respective flow arrows 112 and 114. Air flow is in the direction of an arrow 116.

According to this embodiment of the invention, baffles 120 are located intermediate the ends of the header tubes 102. In the illustrated embodiment, only one baffle 120 is provided in each of the tubes 102 but it is to be understood that additional baffles could be utilized, in which case, baffles would also be located in the header tubes 100 as well. In the illustrated embodiment, a two pass, side to side flow of fluid within the evaporator is provided for. The flow enters the manifold 108 and is distributed to the left hand sides of the header tubes 102. From there, the fluid flows in the direction of an arrow 122 to the left hand side of the header tubes 100 and is then to the right in the header tubes 100 in the direction of an arrow 124. Once the fluid reaches the right hand part of the tubes 100, it then flows in the direction of an arrow 126 to the right hand part of the tubes 102 to exit in the direction of an arrow 128 to the manifold 110.

Though not shown herein, it is also within the contemplation of the invention that baffles be located in both the manifolds and in the header tubes in which case combinations of front to back or back to front and side to side multipass flow can be achieved as desired.

## Claims

**1.** An evaporator comprising:

a plurality of heat exchange modules each comprised of elongated, parallel, upper and lower headers and a plurality of tubes mounted between the headers along their lengths and extending therefrom in side by side relation;

said tubes, in the direction transversely of the headers, having a lesser dimension than the headers;

said modules being stacked and assembled together with the corresponding tubes in the modules in alignment with each other;

fins extending between adjacent tubes in each module; and,

upper and lower manifolds, the upper manifold being in fluid communication with said upper headers at one end thereof and the lower manifold being in fluid communication with said lower headers at an end thereof corresponding to said one end.

**2.** The evaporator of Claim 1 wherein said lower headers are defined by header tubes and are in sealing abutment defined by a braze between adjacent header tubes along the length thereof.

**3.** The evaporator of Claim 2 wherein said header tubes are generally circular in cross section.

**4.** The evaporator of Claim 1 wherein there are at least two of said modules and at least one baffle in one of said manifolds and located to cause fluid flowing in said evaporator to flow serially through said modules in at least two passes.

**5.** The evaporator of Claim 1 wherein there are at least three of said modules and at least one baffle in one of said manifolds and located to cause fluid flowing in said evaporator to flow serially through said modules in at least three passes.

**6.** The evaporator of Claim 1 wherein said modules are assembled to define a core having a core depth of about two inches or less, said fins are serpentine fins, and there are at least about eighteen fins per inch of said tubes.

**7.** An evaporator comprising:

a plurality of at least two heat exchange units each comprised of elongated, upper and lower headers and a plurality of tubes mounted between the headers along their lengths and extending therefrom in side by side relation;

said tubes, in the direction transversely of the headers, having a lesser dimension than the headers;

said units being stacked and assembled together with the corresponding tubes in the units in alignment with each other;

fins extending between adjacent tubes in each unit;

upper and lower manifolds respectively in fluid communication with said upper and lower headers; and,

at least one baffle in one of said manifolds and located to cause fluid flowing in said evaporator to flow serially through said units in at least two passes.

**8.** The evaporator of Claim 7 wherein said manifolds are tubes and said baffles seal the interior of the corresponding tube.

**9.** The evaporator of Claim 7 wherein said units are assembled to define a core having a core depth of about two inches or less, said fins are serpentine fins, and there are at least about eighteen fins per inch of said tubes.

**10.** An evaporator comprising:

a plurality of heat exchange units each comprised of elongated upper and lower headers and a plurality of tubes mounted between the headers along their length and extending therefrom in side by side relation;

said tubes, in the direction transversely of the header, having a lesser dimension than the header;

said units being stacked and assembled together with the corresponding tubes in the units in alignment with each other to define a core;

sets of serpentine fins extending between adjacent tubes in each unit;

said core having a depth of no more than about two inches or less;

said fins having a fin density of at least about eighteen fins per inch.

**11.** An evaporator comprising:

a plurality of heat exchange modules each comprised of elongated, parallel, first and second headers and a plurality of tubes mounted between the headers along their lengths and extending therefrom in side by side relation;

said tubes, in the direction transversely of the headers, having a lesser dimension than the headers;

said modules being stacked and assembled together with the corresponding tubes in the modules in alignment with each other;

fins extending between adjacent tubes in each module; and,

first and second manifolds, the first manifold being in fluid communication with some of said headers at one end thereof and the lower manifold being in fluid communication with some of said headers at an end thereof; and

baffles in said headers to cause fluid flowing in said evaporator to flow serially through parts of each module in at least two passes.

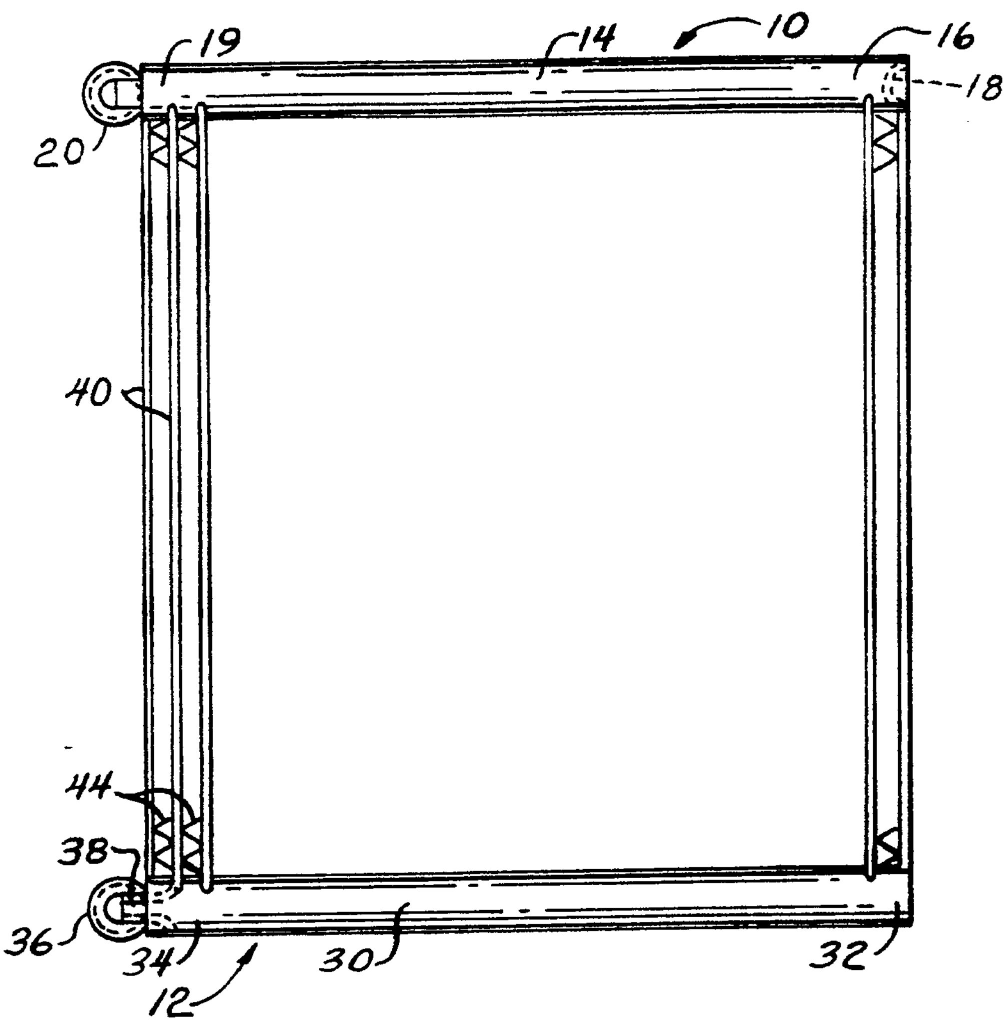

10
14
19
16
18
20
40
44
38
36
34
30
32
12

FIG. 1

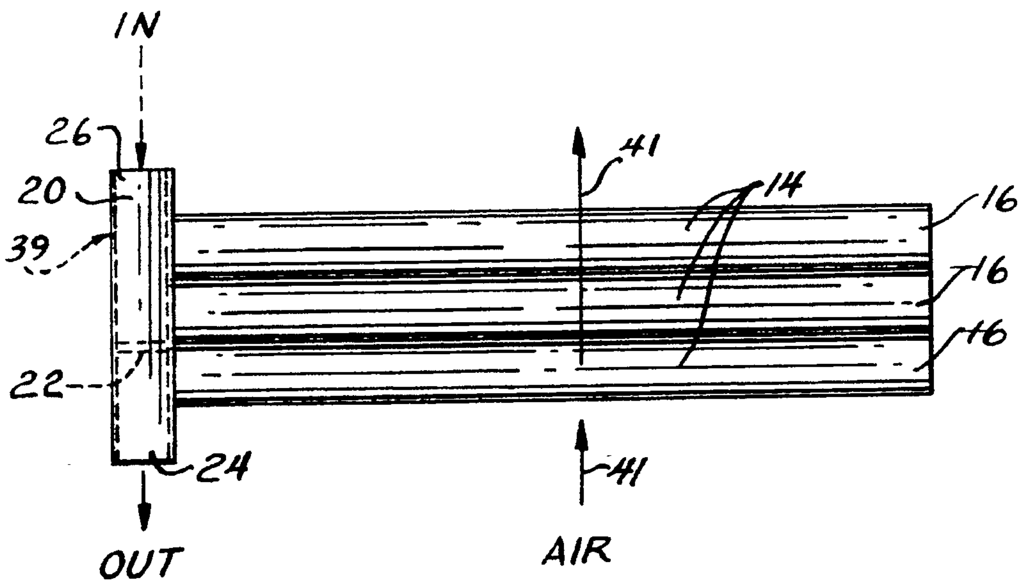

IN
26
20
39
22
24
OUT
41
14
16
16
16
41
AIR

FIG. 2

FIG. 3

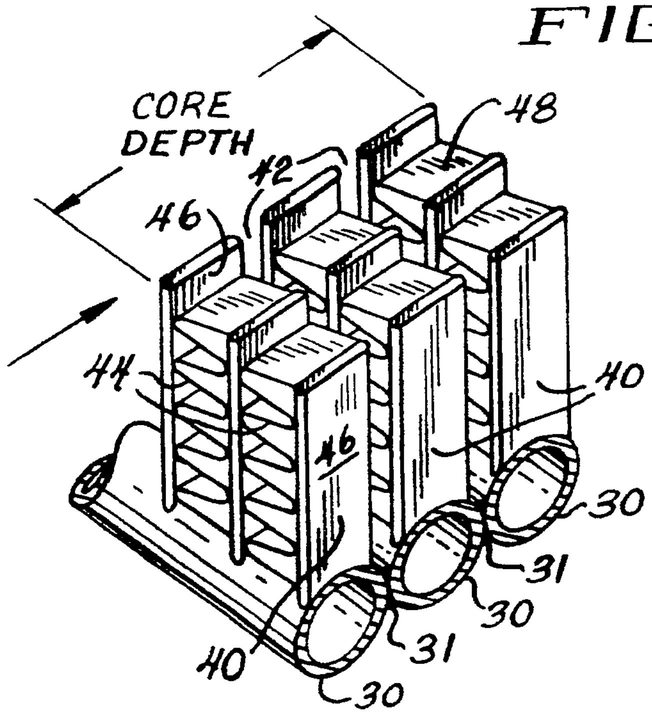



FIG. 4

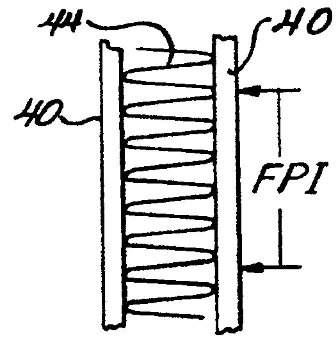



FIG. 5

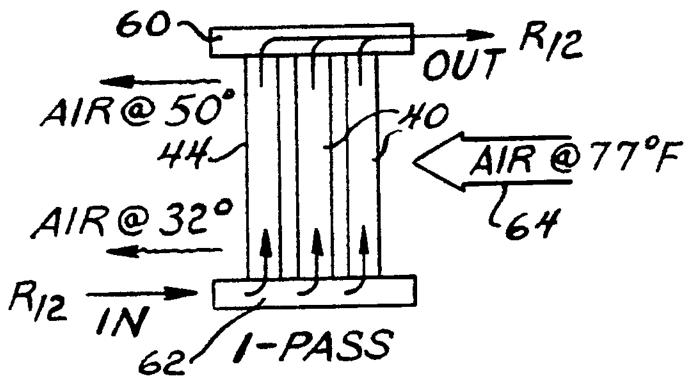
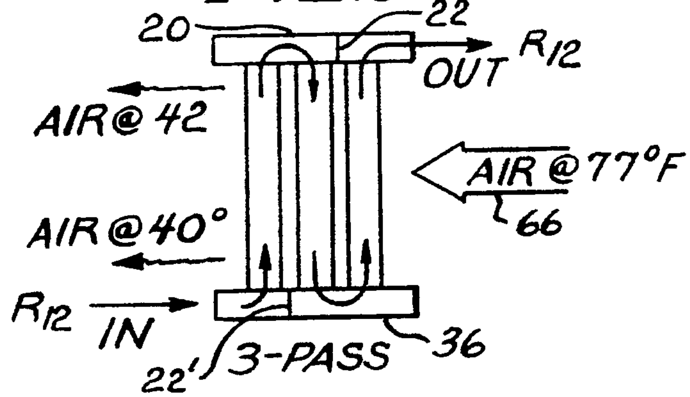



FIG. 6



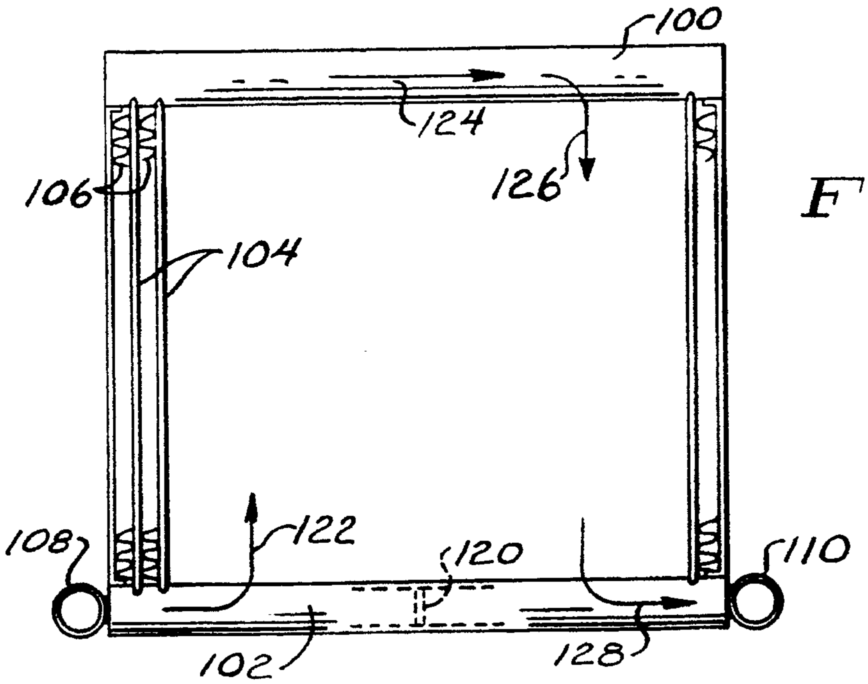



FIG. 7

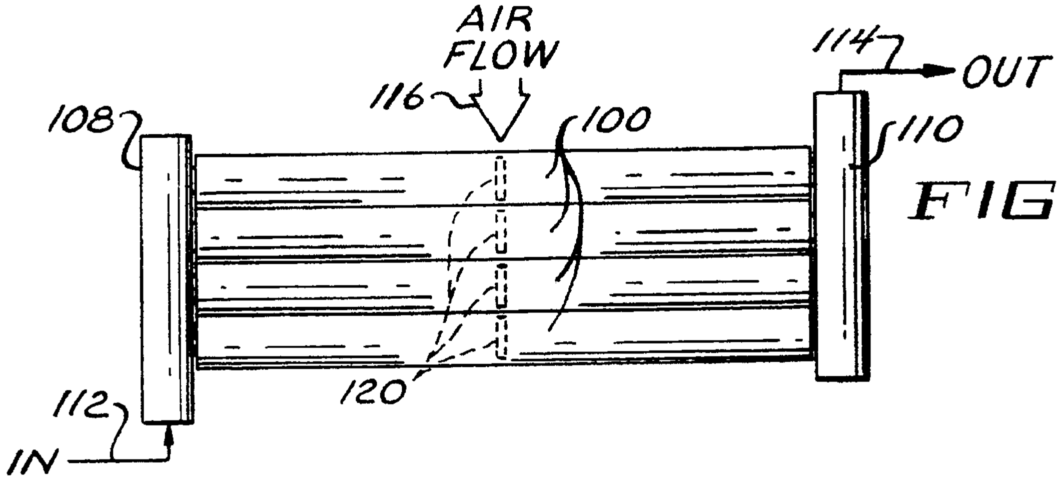



FIG. 8

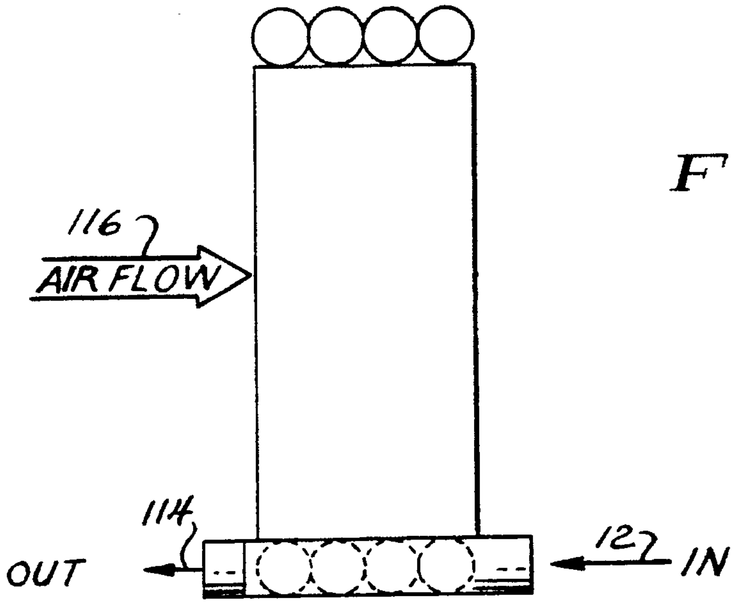



FIG. 9